(i) The dates, number, duration, and results of each sample taken, and a description of the procedure used to determine representative personal exposures;

(ii) A description of the sampling and analytical methods used;

(iii) A description of the type of respirator and personal protective clothing and equipment worn, if any; and

(iv) The name, social security number, and job classification of each person monitored and of all other persons whose exposure the monitoring is intended to represent; and

(v) The exposure levels to which monitored persons were subjected, even if this level is below the PEL.

(b) *Medical record.* (1) The employer shall maintain an accurate medical record for each employee subjected to medical surveillance specified in §197.560 for three years after the employee's employment is terminated.

(2) The record must include—

(i) The name and social security number of the employee;

(ii) The physician's written opinion on the initial, periodic, and special examinations of the employee, including the results of medical examinations and tests and all opinions and recommendations;

(iii) A list of medical complaints, if any, by the employee related to exposure to benzene;

(iv) A copy of the information provided to the physician required in §197.560(f)(2) through (f)(5); and

(v) A copy of the employee's medical and work history related to exposure to benzene or other hematologic toxin.

(c) *Availability of records.* (1) All records required to be maintained by this section must be made available upon request to the Coast Guard.

(2) Records of personal exposure monitoring in compliance with (a) of this section must be provided upon request to persons involved in the operation.

(3) A copy of each item entered into the medical record in compliance with paragraph (b) of this section for a particular employee must be given to that employee at the time the item is entered into the medical record.

(4) Medical records required by paragraph (b) of this section must be provided to persons upon the written request of the subject employee.

(d) *Transfer of records.* (1) If the employer ceases to do business and there is no successor to receive and retain the records for the prescribed period, the employer shall make the best effort to transfer all records required in paragraphs (a) and (b) of this section relating to the affected employees to those employees for their disposition. Before transferring medical records to former employees, the employer shall determine whether any forwarding address provided by the employee is still valid and whether the employee desires the records. If a current or former employee refuses to accept the records or does not respond to notification of their availability, the records shall be destroyed.

(2) If the employer ceases to engage in operations involving benzene, the employer shall retain the records for inspection unless the employee requests them as provided in §197.570(c).

(e) *Confidentiality of records.* Except as specifically required by this Subpart, the employer shall keep confidential all records required to be maintained by this Subpart.

§ 197.575 Observation of monitoring.

(a) Persons involved in benzene operations or their representatives must be provided with an opportunity to observe all monitoring in compliance with §197.540. Coast Guard officials may also observe all monitoring in compliance with §197.540.

(b) When observation of monitoring requires entry into regulated areas, the observers shall use respirator and personal protective clothing and equipment approved in compliance with this subpart and comply with §197.530.

§ 197.580 Appendices.

(a) Appendices A through D and F of this subpart contain technical information on benzene and its effects and provide guidance for medical surveillance, monitoring, and measuring. The appendices are informational and advisory and do not create mandatory requirements.

(b) Appendix E of this subpart contains tests and procedures for fitting respirators. As required by

§ 197.550(d)(1), compliance with appendix E of this subpart is mandatory.

APPENDIX A TO SUBPART C TO PART 197—SAMPLE SUBSTANCE SAFETY DATA SHEET, BENZENE

I. Substance Identification

(a) *Substance:* Benzene.

(b) *Performance standard exposure limits:*

(1) Airborne: The maximum time-weighted average (TWA) exposure limit is one part of benzene vapor per million parts of air (one ppm) for an eight-hour workday and the maximum short-term exposure limit (STEL) is five ppm for any 15-minute period.

(2) Dermal: Eye contact must be prevented and skin contact with liquid benzene must be limited.

(c) *Appearance and odor:* Benzene is a clear, colorless liquid with a pleasant, sweet odor. The odor of benzene does not provide adequate warning of its hazard.

II. Health Hazard Data

(a) *Ways in which benzene affects your health.* Benzene can affect your health if you inhale it or if it comes in contact with your skin or eyes. Benzene is also harmful if you swallow it.

(b) *Effects of overexposure.* (1) Short-term (acute) overexposure: If you are overexposed to high concentrations of benzene, well above the levels where its odor is first recognizable, you may feel breathless, irritable, euphoric, or giddy and you may experience irritation in your eyes, nose, and respiratory tract. You may develop a headache, feel dizzy, nauseated, or intoxicated. Severe exposures may lead to convulsions and loss of consciousness.

(2) Long-term (chronic) exposure: Repeated or prolonged exposure to benzene, even at relatively low concentrations, may result in various blood disorders ranging from anemia to leukemia, an irreversible, fatal disease. Many blood disorders associated with benzene exposure may occur without symptoms.

III. Protective Clothing and Equipment

(a) *Respirators.* Respirators are required for those operations in which engineering controls or work practice controls are not feasible for reducing exposure to the permissible level or are not chosen as the method of complying with the performance standard. If respirators are worn, they must have joint Mine Safety and Health Administration and the National Institute for Occupational Safety and Health (NIOSH) seal of approval. Cartridges or canisters must be replaced before the end of their service life, or the end of the shift, whichever occurs first. If you experience difficulty breathing while wearing a respirator, you may request a positive pressure respirator from your employer. You must be thoroughly trained to use the assigned respirator, and the training will be provided by your employer.

(b) *Protective clothing.* You must wear appropriate protective clothing (such as boots, gloves, sleeves, and aprons) over any parts of your body that could be exposed to liquid benzene.

(c) *Eye and face protection.* You must wear splash-proof safety goggles if it is possible that benzene may get into your eyes. In addition, you must wear a face shield if your face could be splashed with benzene liquid.

IV. Emergency and First Aid Procedures

(a) *Eye and face exposure.* If benzene is splashed in your eyes, wash it out immediately with large amounts of water. If irritation persists or vision appears to be affected, see a doctor as soon as possible.

(b) *Skin exposure.* If benzene is spilled on your clothing or skin, remove the contaminated clothing and wash the exposed skin with large amounts of water and soap immediately. Wash contaminated clothing before you wear it again.

(c) *Breathing.* If you or any other person breathes in large amounts of benzene, get the exposed person to fresh air at once. Apply artificial respiration if breathing has stopped. Call for medical assistance or a doctor as soon as possible. Never enter any vessel or confined space where the benzene concentration might be high without proper safety equipment and with at least one other person present who will stay outside. A life line should be used.

(d) *Swallowing.* If benzene has been swallowed and the subject is conscious, do not induce vomiting. Call for medical assistance or a doctor immediately.

V. Medical Requirements

If you will be exposed to benzene at a concentration at or above 0.5 ppm as an eight-hour time-weighted average or have been exposed at or above 10 ppm in the past while employed by your current employer, your employer may be required by 46 CFR 197.560 to provide a medical examination and history and laboratory tests. These tests must be provided without cost to you. In addition, if you are accidentally exposed to benzene (either by ingestion, inhalation, or skin/eye contact) under emergency conditions known or suspected to constitute a toxic exposure to benzene, your employer is required to make special laboratory tests available to you.

VI. Observation of Monitoring

The employer is required to conduct monitoring that is representative of your exposure to benzene, and you or your designated representative are entitled to observe the monitoring procedure. You are entitled to

observe the steps taken in the measurement procedure and to record the results obtained. When the monitoring procedure is taking place in an area where respirators or personal protective clothing and equipment are required to be worn, you or your representative must wear the protective clothing and equipment (See 46 CFR 197.575.)

VII. Access to Records

You or your representative may see the records of monitoring of your exposure to benzene upon written request to your employer. Your medical examination records may be furnished to you, your physician, or a representative designated by you. (See 46 CFR 197.570(c).)

VIII. Precautions for Safe Use, Handling, and Storage

Benzene liquid is highly flammable. Benzene vapor may form explosive mixtures in air. All sources of ignition must be controlled. Use non-sparking tools when opening or closing benzene containers. Fire extinguishers, where required, must be readily available. Know where they are located and how to operate them. Smoking is prohibited in areas where benzene is used or stored.

APPENDIX B TO SUBPART C TO PART 197—SUBSTANCE TECHNICAL GUIDELINES, BENZENE

I. Physical and Chemical Data

(a) *Substance identification.* (1) Synonyms: Benzol, benzole, coal naphtha, cyclohexatriene, phene, phenyl hydride, pyrobenzol. (Benzin, petroleum benzin, and benzine do not contain benzene).

(2) Formula: C_6 H_6 (CAS Registry Number: 71–43–2).

(b) *Physical data.* (1) Boiling point (760 mm Hg): 80.1 °C (176 °F).

(2) Specific gravity (water = 1): 0.879.

(3) Vapor density (air = 1): 2.7.

(4) Melting point: 5.5 °C (42 °F).

(5) Vapor pressure at 20 °C (68 °F): 75 mm Hg.

(6) Solubility in water: .06%.

(7) Evaporation rate (ether = 1): 2.8.

(8) Appearance and odor: Clear, colorless liquid with a distinctive sweet odor.

II. Fire, Explosion, and Reactivity Hazard Data

(a) *Fire.* (1) Flash point (closed cup): −11 °C (12 °F).

(2) Autoignition temperature: 580 °C (1076 °F).

(3) Flammable limits in air, % by volume: Lower: 1.3%, Upper: 7.5%.

(4) Extinguishing media: Carbon dioxide, dry chemical, or foam.

(5) Special fire fighting procedures: Do not use a solid stream of water, because it will scatter and spread the fire. Fine water spray may be used to keep fire-exposed containers cool.

(6) Unusual fire and explosion hazards: Benzene is a flammable liquid. Its vapors can form explosive mixtures. All ignition sources must be controlled when benzene is used, handled, or stored. Areas where liquid or vapor may be released are considered hazardous locations. Benzene vapors are heavier than air. Thus, benzene vapors may travel along the deck and ground and be ignited by open flames or sparks at locations remote from the site at which benzene is handled.

(7) Benzene is classified as a flammable liquid for the purpose of conforming to the requirements of 49 CFR 172.101 concerning the designation of materials as hazardous materials. Locations where benzene may be present in quantities sufficient to produce explosive or ignitable mixtures are considered Class I Group D locations for the purposes of conforming to the requirements of 46 CFR parts 30 through 40, 151, and 153 when determining the requirements for electrical equipment as specified in Subchapter J (Electrical engineering).

(b) *Reactivity.* (1) Conditions contributing to instability: Heat.

(2) Incompatibility: Heat and oxidizing materials.

(3) Hazardous decomposition products: Toxic gases and vapors (such as carbon monoxide).

III. Spill and Leak Procedures

(a) *Steps to be taken if the material is released or spilled.* As much benzene as possible should be absorbed with suitable materials, such as dry sand or earth. That remaining must be flushed with large amounts of water. Do not flush benzene into a confined space, such as a sewer, because of explosion danger. Remove all ignition sources. Ventilate enclosed places.

(b) *Waste disposal method.* Disposal methods must conform to state and local regulations. If allowed, benzene may be disposed of (a) by absorbing it in dry sand or earth and disposing in a sanitary landfill, (b), if in small quantities, by removing it to a safe location away from buildings or other combustible sources or by pouring onto dry sand or earth and cautiously igniting it, and (c), if in large quantities, by atomizing it in a suitable combustion chamber.

APPENDIX C TO SUBPART C TO PART 197—MEDICAL SURVEILLANCE GUIDELINES FOR BENZENE

I. Route of Entry

Inhalation; skin absorption.

II. Toxicology

Benzene is primarily an inhalation hazard. Systemic absorption may cause depression of

the hematopoietic system, pancytopenia, aplastic anemia, and leukemia. Inhalation of high concentrations may affect the functioning of the central nervous system. Aspiration of small amounts of liquid benzene immediately causes pulmonary edema and hemorrhage of pulmonary tissue. There is some absorption through the skin. Absorption may be more rapid in the case of abraded skin or if it is present in a mixture or as a contaminant in solvents which are readily absorbed. The defatting action of benzene may produce primary irritation due to repeated or prolonged contact with the skin. High concentrations are irritating to the eyes and the mucous membranes of the nose and respiratory tract.

III. Signs and Symptoms

Direct skin contact with benzene may cause erythema. Repeated or prolonged contact may result in drying, scaling dermatitis or development of secondary skin infections. In addition, benzene is absorbed through the skin. Local effects of benzene vapor or liquid on the eye are slight. Only at very high concentrations is there any smarting sensation in the eye. Inhalation of high concentrations of benzene may have an initial stimulatory effect on the central nervous system characterized by exhilaration, nervous excitation, or giddiness, followed by a period of depression, drowsiness, or fatigue. A sensation of tightness in the chest accompanied by breathlessness may occur and ultimately the victim may lose consciousness. Tremors, convulsions, and death may follow from respiratory paralysis or circulatory collapse in a few minutes to several hours following severe exposures.

The detrimental effect on the blood-forming system of prolonged exposure to small quantities of benzene vapor is of extreme importance. The hematopoietic system is the chief target for benzene's toxic effects which are manifested by alterations in the levels of formed elements in the peripheral blood. These effects may occur at concentrations of benzene which may not cause irritation of mucous membranes or any unpleasant sensory effects. Early signs and symptoms of benzene morbidity are varied. Often, they are not readily noticed and are non-specific. Complaints of headache, dizziness, and loss of appetite may precede or follow clinical signs. Rapid pulse and low blood pressure, in addition to a physical appearance of anemia, may accompany a complaint of shortness of breath and excessive tiredness. Bleeding from the nose, gums, or mucous membranes and the development of purpuric spots (small bruises) may occur as the condition progresses. Clinical evidence of leukopenia, anemia, and thrombocytopenia, singly or in combination, may be among the first signs.

Bone marrow may appear normal, aplastic, or hyperplastic and may not, in all situations, correlate with peripheral blood forming tissues. Because of variations in the susceptibility to benzene morbidity, there is no ''typical'' blood picture. The onset of effects of prolonged benzene exposure may be delayed for many months or years after the actual exposure has ceased. Identification or correlation with benzene exposure must be sought out in the occupational history.

IV. Treatment of Acute Toxic Effects

Remove from exposure immediately. Make sure you are adequately protected and do not risk being overcome by fumes. Give oxygen or artificial resuscitation, if indicated. Flush eyes, wash skin if contaminated, and remove all contaminated clothing. Symptoms of intoxication may persist following severe exposures. Recovery from mild exposures is usually rapid and complete.

V. Surveillance and Preventive Considerations

(a) *General.* The principal effects of benzene exposure addressed in 46 CFR part 197, subpart C, appendix A, are pathological changes in the hematopoietic system, reflected by changes in the peripheral blood and manifested clinically as pancytopenia, aplastic anemia, or leukemia. Consequently, the medical surveillance program specified in 46 CFR 197.560 is designed to observe, on a regular basis, blood indices for early signs of these effects. Although early signs of leukemia are not usually available, emerging diagnostic technology and innovative regimes are making consistent surveillance for leukemia, as well as other hematopoietic effects, more and more beneficial.

Initial and periodic medical examinations must be provided as required in 46 CFR 197.560. There are special provisions for medical tests in the event of hematologic abnormalities or emergencies.

The blood values which require referral to a hematologist or internist are noted in 46 CFR 197.560(d) (i), (ii), and (iii). That section specifies that, if blood abnormalities persist, the employee must be referred unless the physician has good reason to believe that the referral is unnecessary. Examples of conditions that might make a referral unnecessary despite abnormal blood limits are iron or folate deficiency, menorrhagia, or blood loss due to some unrelated medical abnormality.

Symptoms and signs of benzene toxicity can be non-specific. Only a detailed history and appropriate investigative procedures will enable a physician to rule out or confirm conditions that place the employee at increased risk. To assist the examining physician with regard to which laboratory tests are necessary and when to refer an employee

to the specialist, the following guidelines have been established.

(b) *Hematology Guidelines.* A minimum battery of tests is to be performed by strictly standardized methods.

(1) Red cell, white cell, platelet counts, white blood cell differential, hematocrit, and red cell indices must be performed by an accredited laboratory. The normal ranges for the red cell and white cell counts are influenced by altitude, race, and sex and, therefore, should be determined by an accredited laboratory in the specific area where the tests are performed.

Either a decline from an absolute normal or from an individual's base line to a subnormal value or a rise to a supra-normal value are indicative of potential toxicity, particularly if all blood parameters decline. The normal total white blood count is approximately 7,200/mm^3 plus or minus 3,000. For cigarette smokers, the white count may be higher and the upper range may be 2,000 cells higher than normal for the laboratory. In addition, infection, allergies, and some drugs may raise the white cell count. The normal platelet count is approximately 250,000 with a range of 140,000 to 400,000. Counts outside this range should be regarded as possible evidence of benzene toxicity.

Certain abnormalities found through routine screening are of greater significance in the benzene-exposed worker and require prompt consultation with a specialist, namely:

(i) Thrombocytopenia.

(ii) A trend of decreasing white cell, red cell, or platelet indices in an individual over time is more worrisome than an isolated abnormal finding at one test time. The importance of a trend highlights the need to compare an individual's test results to baseline, to previous periodic tests, or to both.

(iii) A constellation or pattern of abnormalities in the different blood indices is of more significance than a single abnormality. A low white count not associated with any abnormalities in other cell indices may be a normal statistical variation. Whereas, if the low white count is accompanied by decreases in the platelet and/or red cell indices, such a pattern is more likely to be associated with benzene toxicity and merits thorough investigation.

Anemia, leukopenia, macrocytosis, or an abnormal differential white blood cell count should alert the physician to investigate further and to refer the patient if repeat tests confirm the abnormalities. If routine screening detects an abnormality, the follow-up tests which may be helpful in establishing the etiology of the abnormality are the peripheral blood smear and the reticulocyte count.

The extreme range of normal for reticulocytes is 0.4 to 2.5 percent of the red cells. The usual range is 0.5 to 1.2 percent of the red cells. A decline in reticulocytes to levels of less than 0.4 percent is to be regarded as possible evidence of benzene toxicity requiring accelerated surveillance (unless another specific cause is found). An increase in reticulocyte levels to above 2.5 percent also may be consistent with, but not characteristic of, benzene toxicity.

(2) A careful examination of the peripheral blood smear is an important diagnostic test. As with the reticulocyte count, the smear should be with fresh uncoagulated blood obtained from a needle tip following venipuncture or from a drop of earlobe blood (capillary blood). If necessary, the smear may, under certain limited conditions, be made from a blood sample anticoagulated with EDTA (but never with oxalate or heparin). When the smear is to be prepared from a specimen of venous blood which has been collected by a commercial Vacutainer® type tube containing neutral EDTA, the smear should be made as soon as possible after the venesection. A delay of up to 12 hours is permissible between the drawing of the blood specimen into EDTA and the preparation of the smear if the blood is stored at refrigerator (not freezing) temperature.

(3) The minimum mandatory observations to be made from the smear are as follows:

(i) The differential white blood cell count.

(ii) Description of abnormalities in the appearance of red cells.

(iii) Description of any abnormalities in the platelets.

(iv) A careful search must be made of every blood smear for immature white cells such as band forms (in more than normal proportion, i.e., over ten percent of the total differential count), any number of metamyelocytes, myelocytes, or myeloblasts. Any nucleate or multinucleated red blood cells should be reported. Large ''giant'' platelets or fragments of megakaryocytes must be recognized.

An increase in the proportion of band forms among the neutrophilic granulocytes is an abnormality deserving special mention. Such an increase may represent a change which should be considered as an early warning of benzene toxicity in the absence of other causative factors (most commonly infection). Likewise, the appearance of metamyelocytes, in the absence of another probable cause, is to be considered a possible indication of benzene-induced toxicity.

An upward trend in the number of basophils, which normally do not exceed about 2.0 percent of the total white cells, is to be regarded as possible evidence of benzene toxicity. A rise in the eosinophil count is less specific but may indicate toxicity if the rise is above 6.0 percent of the total white count.

The normal range of monocytes is from 2.0 to 8.0 percent of the total white count with an average of about 5.0 percent. About 20 percent of individuals reported to have mild but

persisting abnormalities caused by exposure to benzene show a persistent monocytosis. The findings of a monocyte count which persists at more than ten to 12 percent of the normal white cell count (when the total count is normal) or persistence of an absolute monocyte count in excess of 800/mm^3 should be regarded as a possible sign of benzene-induced toxicity.

A less frequent but more serious indication of benzene toxicity is the finding in the peripheral blood of the so-called ''pseudo'' (or acquired) Pelger-Huet anomaly. In this anomaly, many, or sometimes the majority, of the neutrophilic granulocytes possess two round nuclear segments, or, less often, one or three round segments, rather than three normally elongated segments. When this anomaly is not hereditary, it is often, but not invariably, predictive of subsequent leukemia. However, only about two percent of patients who ultimately develop acute myelogenous leukemia show the acquired Pelger-Huet anomaly. Other tests that can be administered to investigate blood abnormalities are discussed below. However, these tests should be undertaken by the hematologist.

An uncommon sign, which cannot be detected from the smear but can be elicited by a ''sucrose water test'' of peripheral blood, is transient paroxysmal nocturnal hemoglobinuria (PNH). This sign may first occur insidiously during a period of established aplastic anemia and may be followed within one to a few years by the appearance of rapidly fatal, acute myelogenous leukemia. Clinical detection of PNH, which occurs in only one or two percent of those destined to have acute myelogenous leukemia, may be difficult. If the ''sucrose water test'' is positive, the somewhat more definitive Ham test, also known as the acid-serum hemolysis test, may provide confirmation.

(v) Individuals documented to have developed acute myelogenous leukemia years after initial exposure to benzene may have progressed through a preliminary phase of hematologic abnormality. In some instances, pancytopenia (i.e., a lowering in the counts of all circulating blood cells of bone marrow origin, but not to the extent implied by the term ''aplastic anemia'') preceded leukemia for many years. Depression of a single blood cell type or platelets may represent a harbinger of aplasia or leukemia. The finding of two or more cytopenias or pancytopenia in a benzene-exposed individual must be regarded as highly suspicious of more advanced, although still reversible, toxicity. Pancytopenia coupled with the appearance of immature cells (myelocytes, myeloblasts, erythroblasts, etc.) with abnormal cells (pseudo Pelger-Huet anomaly, atypical nuclear heterochromatin, etc.) or of unexplained elevations of white blood cells must be regarded as evidence of benzene overexposure, unless proved otherwise. Many severely aplastic patients manifested the ominous finding of five to ten percent myeloblasts in the marrow, occasional myeloblasts and myelocytes in the blood, and 20 to 30 percent monocytes. It is evident that isolated cytopenias, pancytopenias, and even aplastic anemias induced by benzene may be reversible and complete recovery has been reported on cessation of exposure. However, because any of these abnormalities is serious, the employee must immediately be removed from any possible exposure to benzene vapor. Certain tests may substantiate the employee's prospects for progression or regression. One such test would be an examination of the bone marrow, but the decision to perform a bone marrow aspiration or needle biopsy must be made by the hematologist.

The findings of basophilic stippling in circulating red blood cells (usually found in one to five percent of red cells following marrow injury) and detection in the bone marrow of what are termed ''ringed sideroblasts'' must be taken seriously, as they have been noted in recent years to be premonitory signs of subsequent leukemia.

Recently peroxidase-staining of circulating or marrow neutrophil granulocytes, employing benzidine dihydrochloride, have revealed the disappearance of, or diminution in, peroxidase in a sizable proportion of the granulocytes. This has been reported as an early sign of leukemia. However, relatively few patients have been studied to date. Granulocyte granules are normally strongly peroxidase positive. A steady decline in leukocyte alkaline phosphatase has also been reported as suggestive of early acute leukemia. Exposure to benzene may cause an early rise in serum iron, often but not always associated with a fall in the reticulocyte count. Thus, serial measurements of serum iron levels may provide a means of determining whether or not there is a trend representing sustained suppression of erythropoiesis.

Measurement of serum iron and determination of peroxidase and of alkaline phosphatase activity in peripheral granulocytes can be performed in most pathology laboratories. Peroxidase and alkaline phosphatase staining are usually undertaken when the index of suspicion for leukemia is high.

APPENDIX D TO SUBPART C TO PART 197—SAMPLING AND ANALYTICAL METHODS FOR BENZENE MONITORING—MEASUREMENT PROCEDURES

Measurements taken for the purpose of determining employee exposure to benzene are best taken so that the representative average eight-hour exposure may be determined from a single eight-hour sample or two four-hour samples. Short-time interval samples (or grab samples) may also be used to determine average exposure level if a minimum of

five measurements are taken in a random manner over the eight-hour work shift. In random sampling, any portion of the work shift has the same chance of being sampled as any other. The arithmetic average of all random samples taken on one work shift is an estimate of an employee's average level of exposure for that work shift. Air samples should be taken in the employee's breathing zone (i.e., air that would most nearly represent that inhaled by the employee). Sampling and analysis must be performed with procedures meeting the requirements of 46 CFR part 197, subpart C.

There are a number of methods available for monitoring employee exposures to benzene. The sampling and analysis may be performed by collection of the benzene vapor on charcoal adsorption tubes, with subsequent chemical analysis by gas chromatography. Sampling and analysis also may be performed by portable direct reading instruments, real-time continuous monitoring systems, passive dosimeters, or other suitable methods. The employer is required to select a monitoring method which meets the accuracy and precision requirements of 46 CFR 197.540(a)(6) for the weather conditions expected. Section 197.540(a)(6) requires that monitoring must have an accuracy, to a 95 percent confidence level, of not less than plus or minus 25 percent for concentrations of benzene greater than or equal to 0.5 ppm.

In developing the following analytical procedures, the OSHA Laboratory modified NIOSH Method S311 and evaluated it at a benzene air concentration of one ppm. A procedure for determining the benzene concentration in bulk material samples was also evaluated. This work, as reported in OSHA Laboratory Method No. 12, includes the following two analytical procedures:

I. OSHA Method 12 for Air Samples

Analyte: Benzene.

Matrix: Air.

Procedure: Adsorption on charcoal, desorption with carbon disulfide, analysis by gas chromatograph.

Detection limit: 0.04 ppm.

Recommended air volume and sampling rate: 10 liter at 0.2 liter/min.

1. Principle of the method

1.1. A known volume of air is drawn through a charcoal tube to trap the organic vapors present.

1.2. The charcoal in the tube is transferred to a small, stoppered vial and the analyte is desorbed with carbon disulfide.

1.3. An aliquot of the desorbed sample is injected into a gas chromatograph.

1.4. The area of the resulting peak is determined and compared with areas obtained from standards.

2. Advantages and disadvantages of the method

2.1. The sampling device is small, portable, and involves no liquids. Interferences are minimal and most of those which do occur can be eliminated by altering chromatographic conditions. The samples are analyzed by means of a quick, instrumental method.

2.2. The amount of sample which can be taken is limited by the number of milligrams that the tube will hold before overloading. When the sample value obtained for the backup section of the charcoal tube exceeds 25 percent of that found on the front section, the possibility of sample loss exists.

3. Apparatus

3.1. A calibrated personal sampling pump having a flow that can be determined within ± five percent at the recommended flow rate.

3.2. Charcoal tubes: Glass with both ends flame sealed, seven cm long with a six mm O.D. and a four mm I.D., containing two sections of 20/40 mesh activated charcoal separated by a two mm portion of urethane foam. The activated charcoal is prepared from coconut shells and is fired at 600 °C before packing. The adsorbing section contains 100 mg of charcoal and the back-up section 50 mg. A three mm portion of urethane foam is placed between the outlet end of the tube and the back-up section. A plug of silanized glass wool is placed in front of the adsorbing section. The pressure drop across the tube must be less than one inch of mercury at a flow rate of one liter per minute.

3.3. Gas chromatograph equipped with a flame ionization detector.

3.4. Column (10 ft. x 1/8 in. stainless steel) packed with 80/100 Supelcoport coated with 20 percent SP 2100 and 0.1 percent CW 1500.

3.5. An electronic integrator or some other suitable method for measuring peak area.

3.6. Two-milliliter sample vials with Teflon-lined caps.

3.7. Microliter syringes: ten microliter (ten µl) syringe, and other convenient sizes for making standards. One µl syringe for sample injections.

3.8. Pipets: 1.0 ml delivery pipets.

3.9. Volumetric flasks: convenient sizes for making standard solutions.

4. Reagents

4.1. Chromatographic quality carbon disulfide (CS_2). Most commercially available carbon disulfide contains a trace of benzene which must be removed. It can be removed with the following procedure. Heat, under reflux for two to three hours, 500 ml of carbon disulfide, ten ml concentrated sulfuric acid, and five drops of concentrated nitric acid. The benzene is converted to nitrobenzene. The carbon disulfide layer is

removed, dried with anhydrous sodium sulfate, and distilled. The recovered carbon disulfide should be benzene free. (It has recently been determined that benzene can also be removed by passing the carbon disulfide through a 13x molecular sieve).

4.2. Benzene, reagent grade.

4.3. p-Cymene, reagent grade, (internal standard).

4.4. Desorbing reagent. The desorbing reagent is prepared by adding 0.05 ml of p-cymene per milliliter of carbon disulfide. (The internal standard offers a convenient means correcting analytical response for slight inconsistencies in the size of sample injections. If the external standard technique is preferred, the internal standard can be eliminated.)

4.5. Purified GC grade helium, hydrogen, and air.

5. Procedure

5.1. Cleaning of equipment. All glassware used for the laboratory analysis should be properly cleaned and free of organics which could interfere in the analysis.

5.2. Calibration of personal pumps. Each pump must be calibrated with a representative charcoal tube in the line.

5.3. Collection and shipping of samples.

5.3.1. Immediately before sampling, break the ends of the tube to provide an opening at least one-half the internal diameter of the tube (two mm).

5.3.2. The smaller section of the charcoal is used as the backup and should be placed nearest the sampling pump.

5.3.3. The charcoal tube should be placed in a vertical position during sampling to minimize channeling through the charcoal.

5.3.4. Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.

5.3.5. A sample size of 10 liters is recommended. Sample at a flow rate of approximately 0.2 liters per minute. The flow rate should be known with an accuracy of at least ± five percent.

5.3.6. The charcoal tubes should be capped with the supplied plastic caps immediately after sampling.

5.3.7. Submit at least one blank tube (a charcoal tube subjected to the same handling procedures, without having any air drawn through it) with each set of samples.

5.3.8. Take necessary shipping and packing precautions to minimize breakage of samples.

5.4. Analysis of samples.

5.4.1. Preparation of samples. In preparation for analysis, each charcoal tube is scored with a file in front of the first section of charcoal and broken open. The glass wool is removed and discarded. The charcoal in the first (larger) section is transferred to a two ml vial. The separating section of foam is removed and discarded and the second section is transferred to another capped vial. These two sections are analyzed separately.

5.4.2. Desorption of samples. Before analysis, 1.0 ml of desorbing solution is pipetted into each sample container. The desorbing solution consists of 0.05 µl internal standard per milliliter of carbon disulfide. The sample vials are capped as soon as the solvent is added. Desorption should be done for 30 minutes with occasional shaking.

5.4.3. GC conditions. Typical operating conditions for the gas chromatograph are as follows:

1. 30 ml/min (60 psig) helium carrier gas flow.
2. 30 ml/min (40 psig) hydrogen gas flow to detector.
3. 240 ml/min (40 psig) air flow to detector.
4. 150 °C injector temperature.
5. 250 °C detector temperature.
6. 100 °C column temperature.

5.4.4. Injection size. One µl.

5.4.5. Measurement of area. The peak areas are measured by an electronic integrator or some other suitable form of area measurement.

5.4.6. An internal standard procedure is used. The integrator is calibrated to report results in ppm for a 10 liter air sample after correction for desorption efficiency.

5.5. Determination of desorption efficiency.

5.5.1. Importance of determination. The desorption efficiency of a particular compound may vary from one laboratory to another and from one lot of chemical to another. Thus, it is necessary to determine, at least once, the percentage of the specific compound that is removed in the desorption process, provided the same batch of charcoal is used.

5.5.2. Procedure for determining desorption efficiency. The reference portion of the charcoal tube is removed. To the remaining portion, amounts representing 0.5X, 1X, and 2X (X represents target concentration) based on a 10 liter air sample, are injected into several tubes at each level. Dilutions of benzene with carbon disulfide are made to allow injection of measurable quantities. These tubes are then allowed to equilibrate at least overnight. Following equilibration, they are analyzed following the same procedure as the samples. Desorption efficiency is determined by dividing the amount of benzene found by amount spiked on the tube.

6. Calibration and standards

A series of standards varying in concentration over the range of interest is prepared and analyzed under the same GC conditions that will be used on the samples. A calibration curve is prepared by plotting concentration (µg/ml) versus peak area.

7. Calculations

Benzene air concentration can be calculated from the following equation:

$mg/m^3=(A)(B)/(C)(D)$

Where: A=µg/ml benzene, obtained from the calibration curve; B=desorption volume (one ml); C=liters of air sampled; and D=desorption efficiency.

The concentration in mg/m^3 can be converted to ppm (at 25° and 760 mm) with following equation:

$ppm=(mg/m^3)(24.46)/(78.11)$.

Where: 24.46=molar volume of an ideal gas 25 °C and 760 mm; and 78.11=molecular weight of benzene.

8. Backup data

8.1 Detection limit—Air Samples. The detection limit for the analytical procedure is 1.28 ng with a coefficient of variation of 0.023 at this level. This would be equivalent to an air concentration of 0.04 ppm for a 10 liter air sample. This amount provided a chromatographic peak that could be identifiable in the presence of possible interferences. The detection limit data were obtained by making one µl injections of a 1.283 µg/ml standard.

Injection	Area count	
1	655.4	
2	617.5	
3	662.0	X=640.2
4	641.1	SD=14.9
5	636.4	CV=0.023
6	629.2	

8.2 Pooled coefficient of variation—Air Samples. The pooled coefficient of variation for the analytical procedure was determined by one µl replicate injections of analytical standards. The standards were 16.04, 32.08, and 64.16 µg/ml, which are equivalent to 0.5, 1.0, and 2.0 ppm for a 10 liter air sample respectively.

8.3 Storage data—Air Samples. Samples were generated at 1.03 ppm benzene at 80% relative humidity, 22 °C, and 643 mm. All samples were taken for 50 minutes at 0.2 liters/min. Six samples were analyzed immediately and the rest of the samples were divided into two groups by fifteen samples each. One group was stored at refrigerated temperature of −25 °C and the other group was stored at ambient temperature (approximately 23 °C). These samples were analyzed over a period of fifteen days. The results are tabulated below.

Injection	Area counts		
	0.5 ppm	1.0 ppm	2.0 ppm
1	3996.5	8130.2	16481
2	4059.4	8235.6	16493
3	4052.0	8307.9	16535
4	4027.2	8263.2	16609
5	4046.8	8291.1	16552
6	4137.9	8288.8	16618
X=	4053.3	8254.0	16548.3
SD=	47.2	62.5	57.1
CV=	0.0116	0.0076	0.0034

CV=0.008.

PERCENT RECOVERY

Day analyzed	Refrigerated			Ambient		
0	97.4	98.7	98.9	97.4	98.7	98.9
0	97.1	100.6	100.9	97.1	100.6	100.9
2	95.8	96.4	95.4	95.4	96.6	96.9
5	93.9	93.7	92.4	92.4	94.3	94.1
9	93.6	95.5	94.6	95.2	95.6	96.6
13	94.3	95.3	93.7	91.0	95.0	94.6
15	96.8	95.8	94.2	92.9	96.3	95.9

8.4 Desorption data. Samples were prepared by injecting liquid benzene onto the A section of charcoal tubes. Samples were prepared that would be equivalent to 0.5, 1.0, and 2.0 ppm for a 10 liter air sample.

PERCENT RECOVERY

Sample	0.5 ppm	1.0 ppm	2.0 ppm
1	99.4	98.8	99.5
2	99.5	98.7	99.7
3	99.2	98.6	99.8
4	99.4	99.1	100.0
5	99.2	99.0	99.7
6	99.8	99.1	99.9

PERCENT RECOVERY—Continued

Sample	0.5 ppm	1.0 ppm	2.0 ppm
X=	99.4	98.9	99.8
SD=	0.22	0.21	0.18
C V=	0.0022	0.0021	0.0018

X=99.4.

8.5 Carbon disulfide. Carbon disulfide from a number of sources was analyzed for benzene contamination. The results are given in the following table. The benzene contaminant can be removed with the procedures given in section I.4.1.

Sample	µg Benzene/ml	ppm equivalent (for 10 liter air sample)
ALDRICH Lot 83017 ..	4.20	0.13
BAKER Lot 720364	1.01	0.03
BAKER Lot 822351	1.01	0.03
Malinkrodt Lot WEMP	1.74	0.05
Malinkrodt Lot WDSJ	5.65	0.18
Malinkrodt Lot WHGA	2.90	0.09
Treated CS_2	.....	.....

II. OSHA Laboratory Method No. 12 for Bulk Samples

Analyte: Benzene.

Matrix: Bulk Samples.

Procedure: Bulk samples are analyzed directly by high performance liquid chromatography (HPLC).

Detection limits: 0.01% by volume.

1. Principle of the method

1.1. An aliquot of the bulk sample to be analyzed is injected into a liquid chromatograph.

1.2. The peak area for benzene is determined and compared to areas obtained from standards.

2. Advantages and disadvantages of the method

2.1. The analytical procedure is quick, sensitive, and reproducible.

2.2. Reanalysis of samples is possible.

2.3. Interferences can be circumvented by proper selection of HPLC parameters.

2.4. Samples must be free of any particulates that may clog the capillary tubing in the liquid chromatograph. This may require distilling the sample or clarifying with a clarification kit.

3. Apparatus

3.1. Liquid chromatograph equipped with a UV detector.

3.2. HPLC Column that will separate benzene from other components in the bulk sample being analyzed. The column used for validation studies was a Waters uBondapack C18, 30 cm×3.9 mm.

3.3. A clarification kit to remove any particulates in the bulk if necessary.

3.4. A micro-distillation apparatus to distill any samples if necessary.

3.5. An electronic integrator or some other suitable method of measuring peak areas.

3.6. Microliter syringes—ten µl syringe and other convenient sizes for making standards. 10 µl syringe for sample injections.

3.7. Volumetric flasks, five ml and other convenient sizes for preparing standards and making dilutions.

4. Reagents

4.1. Benzene, reagent grade.

4.2. HPLC grade water, methyl alcohol, and isopropyl alcohol.

5. Collection and shipment of samples

5.1. Samples should be transported in glass containers with Teflon-lined caps.

5.2. Samples should not be put in the same container used for air samples

6. Analysis of samples

6.1. Sample preparation. If necessary, the samples are distilled or clarified. Samples are analyzed undiluted. If the benzene concentration is out of the working range, suitable dilutions are made with isopropyl alcohol.

6.2. HPLC conditions. The typical operating conditions for the high performance liquid chromatograph are:

6.2.1. Mobile phase—Methyl alcohol/water, 50/50.

6.2.2. Analytical wavelength—254 nm.

6.2.3. Injection size—10 µl.

6.3. Measurement of peak area and calibration. Peak areas are measured by an integrator or other suitable means. The integrator is calibrated to report results in % benzene by volume.

7. Calculations

Because the integrator is programmed to report results in % benzene by volume in an undiluted sample, the following equation is used: % Benzene by Volume=A×B.

Where: A=% by volume on report. B=Dilution Factor. (B=one for undiluted sample).

8. Backup data

8.1. Detection limit—Bulk Samples. The detection limit for the analytical procedure for bulk samples is 0.88 µg, with a coefficient of variation of 0.019 at this level. This amount provided a chromatographic peak that could be identifiable in the presence of possible interferences. The detection limit date were obtained by making ten µl injections of a 0.10% by volume standard.

Injection	Area Count	
1	45386	
2	44214	
3	43822	X=44040.1
4	44062	SD=852.5
6	42724	CV=0.019

8.2. Pooled coefficient of variation—Bulk Samples. The pooled coefficient of variation for the analytical procedure was determined by 50 µl replicate injections of analytical standards. The standards were 0.01, 0.02, 0.04, 0.10, 1.0, and 2.0% benzene by volume.

AREA COUNT (PERCENT)

Injection #	0.01	0.02	0.04	0.10	1.0	2.0
1	45386	84737	166097	448497	4395380	9339150
2	44241	84300	170832	441299	4590800	9484900
3	43822	83835	164160	443719	4593200	9557580
4	44062	84381	164445	444842	4642350	9677060
5	44006	83012	168398	442564	4646430	9766240
6	42724	81957	173002	443975	4646260	.....
X=	44040.1	83703.6	167872	444149	4585767	9564986
SD=	852.5	1042.2	3589.8	2459.1	96839.3	166233
CV=	0.0194	0.0125	0.0213	0.0055	0.0211	0.0174

CV=0.017.

APPENDIX E TO SUBPART C TO PART 197—RESPIRATOR FIT TESTS

PROCEDURES

This appendix contains the procedures for properly fitting a respirator to employees who may be exposed to benzene and includes the Initial Fit Tests (IFT), the Qualitative Fit Tests (QLFT), and the Quantitative Fit Test (QNFT).

Note that respirators (negative pressure or positive pressure) must not be worn when conditions prevent a tight seal between the faceplate and the skin or the proper functioning of the inhalation or exhalation valves. In order for a respirator to protect the wearer, the facepiece must make a proper seal against the wearer's face. Several factors can negatively affect the respirator to face seal and reduce the level of protection afforded by the respirator. Among these are facial shape, temple pieces of eyeglasses, facial abnormalities (e.g., scars and indentations) absence of dentures, hair style or length of hair, specific skin conditions, and facial hair. Therefore, nothing can come between or otherwise interfere with the sealing surface of the respirator and the face or interfere with the function of the inhalation or exhalation valves.

I. Initial Fit Tests (IFT)

(a) The test subject must be allowed to select the most comfortable respirator from a selection of respirators of various sizes. The selection must include at least three sizes of elastomeric facepieces for the type of respirator that is to be tested (i.e., three sizes of half mask or three sizes of full facepiece).

(b) Before the selection process, the test subject must be shown how to put on a respirator, how it should be positioned on the face, how to set strap tension, and how to determine a comfortable fit. A mirror must be available to assist the subject in evaluating the fit and positioning the respirator. This instruction is only a preliminary review and must not constitute the subject's formal training on respirator use.

(c) The test subject must be informed that he or she is being asked to select the respirator which provides the most comfortable fit. Each respirator represents a different size and shape and, if fitted and used properly, should provide adequate protection.

(d) The test subject must be instructed to hold each facepiece up to the face and eliminate those facepieces which obviously do not give a comfortable fit.

(e) The more comfortable facepieces must be noted and the most comfortable mask donned and worn at least five minutes to assess comfort. Assistance in assessing comfort may be given by discussing the points in section I(f) of this appendix. If the test subject is not familiar with using a particular respirator, the test subject must be directed to don the mask several times and to adjust the straps each time to become adept at setting proper tension on the straps.

(f) Assessment of comfort must include reviewing the following points with the test subject and allowing the test subject adequate time to determine the comfort of the respirator:

(1) Position of the mask on the nose.

(2) Room for eye protection.

(3) Room to talk.

(4) Position of mask on face and cheeks.

(g) The following criteria must be used to help determine the adequacy of the respirator fit:

(1) Chin properly placed.

(2) Adequate strap tension, not overly tightened.

(3) Fit across nose bridge.

(4) Respirator of proper size to span distance from nose to chin.

(5) Tendency of respirator to slip.

(6) Self-observation in mirror to evaluate fit and respirator position.

(h) The following negative and positive pressure fit tests must be conducted. Before conducting a negative or positive pressure fit test, the subject must be told to seat the mask on the face by moving the head from side-to-side and up and down slowly while taking in a few slow deep breaths Another facepiece must be selected and retested if the test subject fails the fit check tests.

(1) *Positive pressure fit test.* The exhalation valve must be closed off and the subject must exhale gently onto the facepiece. The

face fit is considered satisfactory if a slight positive pressure can be built up inside the facepiece without any evidence of outward leakage of air at the seal. For most respirators this method of leak testing requires the wearer to first remove the exhalation valve cover before closing off the exhalation valve and then carefully replacing it after the test.

(2) *Negative pressure fit test.* The inlet opening of the canister or cartridge(s) must be closed off by covering with the palm of the hand(s) or by replacing the filter seal(s). The subject must inhale gently so that the facepiece collapses slightly and hold his or her breath for ten seconds. If the facepiece remains in its slightly collapsed condition and no inward leakage of air is detected, the tightness of the respirator is considered satisfactory.

(i) The test must not be conducted if the subject has any hair growth between the skin and the facepiece sealing surface, such as stubble beard growth, beard, or long sideburns which cross the respirator sealing surface. Any type of apparel, such as a skull cap or the temple bars of eye glasses, which projects under the facepiece or otherwise interferes with a satisfactory fit must be altered or removed.

(j) If the test subject exhibits difficulty in breathing during the tests, the subject must be referred to a physician trained in respiratory disease or pulmonary medicine to determine whether the test subject can wear a respirator while performing his or her duties.

(k) The test subject must be given the opportunity to wear the successfully fitted respirator for a period of two weeks. If at any time during this period the respirator becomes uncomfortable, the test subject must be given the opportunity to select a different facepiece and to be retested.

(l) Exercise regimen. Before beginning the fit test, the test subject must be given a description of the fit test and of the test subject's responsibilities during the test procedure. The description of the process must include a description of the test exercises that the subject must perform. The respirator to be tested must be worn for at least five minutes before the start of the fit test.

(m) Test Exercises. The test subject must perform the following exercises in the test environment:

(1) Normal breathing. In a normal standing position, without talking, the subject must breathe normally.

(2) Deep breathing. In a normal standing position, the subject must breathe slowly and deeply, taking caution so as to not hyperventilate.

(3) Turning head side to side. Standing in place, the subject must slowly turn his or her head from side to side between the extreme positions on each side. The subject must hold his or her head at each extreme momentarily and inhale.

(4) Moving head up and down. Standing in place, the subject must slowly move his or her head up and down. The subject must be instructed to inhale in the up position (i.e., when looking toward the ceiling).

(5) Talking. The subject must talk slowly and loudly enough so as to be heard clearly by the test conductor. The subject must count backward from 100, recite a memorized poem or song, or read the following passage:

RAINBOW PASSAGE

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond reach, his friends say he is looking for the pot of gold at the end of the rainbow.

(6) Grimace. The test subject must grimace by smiling or frowning.

(7) Bending over. The test subject must bend at the waist as if to touch the toes or, for test environments such as shroud type QNFT units which prohibit bending at the waist, the subject must jog in place.

(8) Normal breathing. Same as exercise 1.

Each test exercise must be performed for one minute, except for the grimace exercise which must be performed for 15 seconds. The test subject must be questioned by the test conductor regarding the comfort of the respirator upon completion of test exercises. If it has become uncomfortable, another respirator must be tried and the subject retested.

(n) The employer shall certify that a successful fit test has been administered to the test subject. The certification must include the following information:

(1) Name of employee.

(2) Type, brand, and size of respirator.

(3) Date of test.

Where QNFT is used, the fit factor, strip chart, or other recording of the results of the test must be retained with the certification. The certification must be maintained until the next fit test is administered.

II. Qualitative Fit Tests (QLFT)

(a) *General.* (1) The employer shall designate specific individuals to administer the respirator qualitative fit test program. The employer may contract for these services.

(2) The employer shall ensure that persons administering QLFT are able to properly prepare test solutions, calibrate equipment, perform tests, recognize invalid tests, and

determine whether the test equipment is in proper working order.

(3) The employer shall ensure that QLFT equipment is kept clean and maintained so as to operate at the parameters for which it was designed.

(b) *Isoamyl acetate tests.* (1) Odor threshold screening test. The odor threshold screening test, performed without wearing a respirator, is intended to determine if the test subject can detect the odor of isoamyl acetate.

(i) Three one-liter glass jars with metal lids must be used.

(ii) Odor free water (e.g. distilled or spring water) at approximately 25 degrees C must be used for the solutions.

(iii) An isoamyl acetate (IAA) (also known at isopentyl acetate) stock solution must be prepared by adding one cc of pure IAA to 800 cc of odor free water in a one liter jar and by shaking the jar for 30 seconds. A new solution must be prepared at least weekly.

(iv) The screening test must be conducted in a room separate from the room used for actual fit testing. The two rooms must be well ventilated but not connected to the same recirculating ventilation system.

(v) An odor test solution must be prepared in a second one-liter jar by placing 0.4 cc of the stock solution into 500 cc of odor free water using a clean dropper or pipette. The solution must be shaken for 30 seconds and allowed to stand for two to three minutes so that the IAA concentration above the liquid may reach equilibrium. This solution must be used for only one day.

(vi) A test blank must be prepared in a third one-liter jar by adding 500 cc of odor free water.

(vii) The odor test jar and the test blank jar must be labeled ''1'' and ''2'' for identification. The labels must be placed on the jar lids so that the labels can be periodically peeled off dried, and switched to maintain the integrity of the test.

(viii) The following instruction must be typed on a card and placed on a table in front of the odor test jar and the test blank jar:

The purpose of this test is to determine if you can smell banana oil at a low concentration. The two bottles in front of you contain water. One of these bottles also contains a small amount of banana oil. Be sure the covers are on tight, then shake each bottle for two seconds. Unscrew the lid of each bottle, one at a time, and sniff at the mouth of the bottle. Indicate to the test conductor which bottle contains banana oil.

(ix) The mixtures in the jars used in the IAA odor threshold screening must be prepared in an area separate from the test area, in order to prevent olfactory fatigue in the test subject.

(x) If the test subject is unable to correctly identify the jar containing the odor test solution, the IAA qualitative fit test must not be performed.

(xi) If the test subject correctly identifies the jar containing the odor test solution, the test subject may proceed to respirator selection and fit testing.

(2) Isoamyl acetate fit test. (i) The fit test chamber must be a clear 55-gallon drum liner or similar device suspended inverted over a two foot diameter frame so that the top of the chamber is about six inches above the test subject's head. The inside top center of the chamber must have a small hook attached.

(ii) Each respirator used for the fitting and fit testing must be equipped with organic vapor cartridges or offer protection against organic vapors. The cartridges or masks must be changed at least weekly.

(iii) After selecting, donning, and properly adjusting a respirator, the test subject must wear the respirator to the fit testing room. This room must be separate from the room used for odor threshold screening and respirator selection and must be well ventilated by an exhaust fan, lab hood, or other device to prevent general room contamination.

(iv) A copy of the test exercises and any prepared text from which the subject is to read must be taped to the inside of the test chamber.

(v) Upon entering the test chamber, the test subject must be given a six inch by five inch piece of paper towel or other porous, absorbent, single-ply material, folded in half and wetted with 0.75 cc of pure IAA. The test subject must hang the wet towel on the hook at the top of the chamber.

(vi) Two minutes must be allowed for the IAA test concentration to stabilize before starting the fit test exercises. This would be an appropriate time to talk with the test subject, to explain the fit test, the importance of the subject's cooperation, and the purpose for the head exercises, or to demonstrate some of the exercises.

(vii) The test subject must be instructed to perform the exercises described in section I(n) of this appendix. If at any time during the test the subject detects the banana like odor of IAA, the test is failed. The subject must be removed quickly from the test chamber and the test area to avoid olfactory fatigue.

(viii) If the test is failed, the subject must return to the selection room, remove the respirator, repeat the odor sensitivity test, select and don another respirator, return to the test chamber, and again take the IAA fit test. The process must continue until a respirator that fits well is found. If the odor sensitivity test is failed, the subject must wait at least five minutes before retesting to allow odor sensitivity to return.

(ix) When a respirator is found that passes the test, the subject must demonstrate the efficiency of the respirator by breaking the face seal and taking a breath before exiting the chamber. If the subject cannot detect the odor of IAA, the test is deemed inconclusive and must be rerun.

(x) When the test subject leaves the chamber, the subject must remove the saturated towel and return it to the person conducting the test. To keep the test area from becoming contaminated, the used towel must be kept in a self-sealing bag to avoid significant IAA concentration build-up in the test chamber for subsequent tests.

(c) *Saccharin solution aerosol test.* The saccharin solution aerosol test is an alternative qualitative test. Although it is the only validated test currently available for use with particulate disposable dust respirators not equipped with high-efficiency filters, it may also be used for testing other respirators. The entire screening and testing procedure must be explained to the test subject before the conduct of the saccharin test threshold screening test.

(1) Saccharin taste threshold screening test. The test, performed without wearing a respirator, is intended to determine whether the test subject can detect the taste of saccharin.

(i) The subject must wear an enclosure about the head and shoulders that is approximately 12 inches in diameter by 14 inches tall with at least the front portion clear. If the enclosure is also used for the saccharin solution aerosol fit test in compliance with section II(c)(2) of this appendix, the enclosure must allow free movements of the head when a respirator is worn. An enclosure substantially similar to the Minnesota, Mining and Manufacturing (3M) hood assembly, parts No. FT 14 and No. FT 15 combined, is adequate.

(ii) The test enclosure must have a ¾ inch hole in front of the test subject's nose and mouth area to accommodate the nebulizer nozzle.

(iii) The test subject must don the test enclosure. Throughout the threshold screening test, the test subject must breathe with mouth wide open and tongue extended.

(iv) Using a DeVilbiss Model 40 Inhalation Medication Nebulizer, the test conductor must spray the threshold check solution in accordance with II(c)(1)(v) of this appendix into the enclosure. The nebulizer must be clearly marked to distinguish it from the fit test solution nebulizer.

(v) The threshold check solution consists of 0.83 grams of sodium saccharin USP in one cc of warm water. It may be prepared by putting one cc of the fit test solution (see section II(c)(2)(iv) of this appendix) in 100 cc of distilled water.

(vi) To produce the aerosol, the nebulizer bulb must be firmly squeezed so that it collapses completely. Then, the bulb must be released and allowed to expand fully.

(vii) The bulb must be squeezed rapidly ten times and the test subject must be asked whether he or she tastes the saccharin.

(viii) If the first response is negative, the ten rapid squeezes must be repeated and the test subject is again asked whether he or she tastes the saccharin.

(ix) If the second response is negative, ten more squeezes are repeated rapidly and the test subject again asked whether the saccharin is tasted.

(x) The test conductor must take note of the number of squeezes required to solicit a taste response.

(xi) If the saccharin is not tasted after 30 squeezes, the test subject may not perform the saccharin fit test.

(xii) If a taste response is elicited, the test subject must be asked to take note of the taste for reference in the fit test.

(xiii) Correct use of the nebulizer means that approximately one cc of liquid is used at a time in the nebulizer body.

(xiv) The nebulizer must be thoroughly rinsed in water, shaken dry, and refilled at least each morning and afternoon or at least every four-hours.

(2) Saccharin solution aerosol fit test. (i) The test subject may not eat, drink (except plain water), or chew gum for 15 minutes before the test.

(ii) The fit test must be conducted with the same type of enclosure used for the saccharin taste threshold screening test in accordance with section II(c)(1) of this appendix.

(iii) The test subject must don the enclosure while wearing the respirator selected in the saccharin taste threshold screening test. The respirator must be properly adjusted and equipped with a particulate filter(s).

(iv) A second DeVilbiss Model 40 Inhalation Medication Nebulizer must be used to spray the fit test solution into the enclosure. This nebulizer must be clearly marked to distinguish it from the nebulizer used for the threshold check solution in accordance with section II(c)(1)(iv) of this appendix.

(v) The fit test solution must be prepared by adding 83 grams of sodium saccharin to 100 cc of warm water.

(vi) The test subject must breathe with mouth wide open and tongue extended.

(vii) The nebulizer must be inserted into the hole in the front of the enclosure and the fit test solution must be sprayed into the enclosure using the same number of squeezes required to elicit a taste response in the screening test in accordance with sections II(c)(1)(vi) through II(c)(1)(xi) of this appendix.

(viii) After generating the aerosol, the test subject must be instructed to perform the exercises in section I(n) of this appendix.

(ix) Every 30 seconds, the aerosol concentration must be replenished using one half the number of squeezes used initially.

(x) The test subject must indicate to the test conductor if, at any time during the fit test, the taste of saccharin is detected.

(xi) If the taste of saccharin is detected, the fit must be deemed unsatisfactory and a different respirator must be tried.

(d) *Irritant fume test.* The irritant fume test is an alternative qualitative fit test.

(1) The respirator to be tested must be equipped with high-efficiency particulate air (HEPA) filters.

(2) The test subject must be allowed to smell a weak concentration of the irritant smoke before the respirator is donned to become familiar with the smoke's characteristic odor.

(3) Both ends of a ventilation smoke tube containing stannic oxychloride, such as the Marine Safety Appliance part No. 5645 or equivalent, must be broken. One end of the smoke tube must be attached to a low flow air pump set to deliver 200 milliliters per minute.

(4) The test subject must be advised that the smoke may be irritating to the eyes and that the subject must keep his or her eyes closed while the test is performed.

(5) The test conductor must direct the stream of irritant smoke from the smoke tube towards the face seal area of the test subject. The test must be started with the smoke tube at least 12 inches from the facepiece, moved gradually to within one inch, and moved around the whole perimeter of the mask

(6) Each test subject who passes the smoke test without evidence of a response must be given a sensitivity check of the smoke from the same tube once the respirator has been removed. This check is necessary to determine whether the test subject reacts to the smoke. Failure to evoke a response voids the fit test.

(7) The fit test must be performed in a location with exhaust ventilation sufficient to prevent general contamination of the testing area by the irritant smoke.

III. Quantitative Fit Tests (ONFT)

(a) *General.* (1) The employer shall designate specific individuals to administer the respirator quantitative fit test program.

(2) The employer shall ensure that persons administering QNFT are able to properly calibrate equipment, perform tests, recognize invalid tests, calculate fit factors, and determine whether the test equipment is in proper working order.

(3) The employer shall ensure that QNFT equipment is kept clean and maintained so as to operate at the parameters for which it was designed.

(b) *Definitions.* (1) *Quantitative fit test* means a test which is performed in a test chamber and in which the normal air-purifying element of the respirator is replaced with a high-efficiency particulate air (HEPA) filter, in the case of particulate QNFT aerosols, or with a sorbent offering contaminant penetration protection equivalent to high-efficiency filters, if the QNFT test agent is a gas or vapor.

(2) *Challenge agent* means the aerosol, gas, or vapor introduced into a test chamber so that its concentration inside and outside of the respirator may be measured.

(3) *Test subject* means the person wearing the respirator for quantitative fit testing.

(4) *Normal standing position* means an erect and straight stance with arms down along the sides and eyes looking straight ahead.

(5) *Maximum peak penetration method* means the method of determining test agent penetration in the respirator as determined by strip chart recordings of the test. The highest peak penetration for a given exercise is taken to be representative of average penetration into the respirator for that exercise.

(6) *Average peak penetration method* means the method of determining test agent penetration into the respirator by using a strip chart recorder, integrator, or computer. The agent penetration is determined by an average of the peak heights on the graph, or by computer integration, for each exercise except the grimace exercise. Integrators or computers which calculate the actual test agent penetration into the respirator for each exercise also may be used in accordance with this method.

(7) *Fit factor* means the ratio of challenge agent concentration outside with respect to the inside of a respirator inlet covering (facepiece or enclosure).

(c) *Apparatus.* (1) Instrumentation. Aerosol generation, dilution, and measurement systems using corn oil or sodium chloride as test aerosols must be used for quantitative fit testing.

(2) Test chamber. The test chamber must be large enough to permit all test subjects to perform freely all required exercises without disturbing the challenge agent concentration or the measurement apparatus. The test chamber must be equipped and constructed so that the challenge agent is effectively isolated from the ambient air, yet is uniform in concentration throughout the chamber.

(3) When testing air-purifying respirators, the normal filter or cartridge element must be replaced with a high-efficiency particulate filter supplied by the same manufacturer.

(4) The sampling instrument must be selected so that a strip chart record may be made of the test showing the rise and fall of the challenge agent concentration with each inspiration and expiration at fit factors of at least 2,000. Integrators or computers which

integrate the amount of test agent penetration leakage into the respirator for each exercise may be used if a record of the readings is made.

(5) The combination of substitute air-purifying elements, challenge agent, and challenge agent concentration in the test chamber must be such that the test subject is not exposed to a concentration of the challenge agent in excess of the established exposure limit for the challenge agent at any time during the testing process.

(6) The sampling port on the test specimen respirator must be placed and constructed so that no leakage occurs around the port (e.g. where the respirator is probed), so that a free air flow is allowed into the sampling line at all times, and so that there is no interference with the fit or performance of the respirator.

(7) The test chamber and test set up must permit the person administering the test to observe the test subject inside the chamber during the test.

(8) The equipment generating the challenge atmosphere must maintain a constant concentration of challenge agent inside the test chamber to within a ten percent variation for the duration of the test.

(9) The time lag (i.e. the interval between an event and the recording of the event on the strip chart, computer, or integrator) must be kept to a minimum. There must be a clear association between the occurrence of an event inside the test chamber and the recording of that event.

(10) The sampling line tubing for the test chamber atmosphere and for the respirator sampling port must be of equal diameter and of the same material. The length of the two lines must be equal.

(11) The exhaust flow from the test chamber must pass through a high-efficiency filter before release.

(12) When sodium chloride aerosol is used, the relative humidity inside the test chamber must not exceed 50 percent.

(13) The limitations of instrument detection must be taken into account when determining the fit factor.

(14) Test respirators must be maintained in proper working order and inspected for deficiencies, such as cracks, missing valves, and gaskets.

(d) *Procedural requirements.* (1) When performing the initial positive or negative pressure test, the sampling line must be crimped closed in order to avoid air pressure leakage during either of these tests.

(2) In order to reduce the amount of QNFT time, an abbreviated screening isoamyl acetate test or irritant fume test may be used in order to quickly identify poor fitting respirators which passed the positive or negative pressure test. When performing a screening isoamyl acetate test, combination high-efficiency organic vapor cartridges or canisters must be used.

(3) A reasonably stable challenge agent concentration must be measured in the test chamber before testing. For canopy or shower curtain type of test units, the determination of the challenge agent stability may be established after the test subject has entered the test environment.

(4) Immediately after the subject enters the test chamber, the challenge agent concentration inside the respirator must be measured to ensure that the peak penetration does not exceed five percent for a half mask or one percent for a full facepiece respirator.

(5) A stable challenge concentration must be obtained before the actual start of testing.

(6) Respirator restraining straps must not be overtightened for testing. The straps must be adjusted by the wearer without assistance from other persons to give a fit reasonably comfortable for normal use.

(7) After obtaining a stable challenge concentration, the test subject must be instructed to perform the exercises described in section I(n) of this appendix. The test must be terminated whenever any single peak penetration exceeds five percent for half masks and one percent for full facepiece respirators. The test subject must be refitted and retested. If two of the three required tests are terminated, the fit is deemed inadequate.

(8) In order to successfully complete a QNFT, three successful fit tests must be conducted. The results of each of the three independent fit tests must exceed the minimum fit factor needed for the class of respirator (e.g., half mask respirator, full facepiece respirator).

(9) Calculation of fit factors. (i) The fit factor must be determined for the quantitative fit test by taking the ratio of the average chamber concentration to the concentration inside the respirator.

(ii) The average test chamber concentration is the arithmetic average of the test chamber concentration at the beginning and of the end of the test.

(iii) The concentration of the challenge agent inside the respirator must be determined by one of the following methods:

(A) Average peak concentration.

(B) Maximum peak concentration.

(C) Integration by calculation of the area under the individual peak for each exercise. This includes computerized integration.

(10) Interpretation of test results. The fit factor established by the quantitative fit testing must be the lowest of the three fit factor values calculated from the three required fit tests.

(11) The test subject must not be permitted to wear a half mask or a full facepiece respirator unless a minimum fit factor equivalent to at least ten times the hazardous exposure level is obtained.

(12) Filters used for quantitative fit testing must be replaced at least weekly, whenever increased breathing resistance is encountered, or whenever the test agent has altered the integrity of the filter media. When used, organic vapor cartridges and canisters must be replaced daily or whenever there is an indication of a breakthrough by a test agent.

APPENDIX F TO SUBPART C TO PART 197—SAMPLE WORKER CERTIFICATION FORM

BENZENE WORKER'S CERTIFICATION

I, _____(Name of worker), certify in accordance with 46 CFR 197.530—

(1) That I have had, within the previous twelve months, at least one medical examination in compliance with 46 CFR 197.560 or 29 CFR 1910.1028;

(2) That the physician conducting the latest medical examination in compliance with paragraph (1) of this certification did not recommend that I be excluded from areas where personal exposure may exceed the action level as defined in 46 CFR 197.505;

(3) That all respirators and personal protective clothing and equipment that I will use while on the vessel meet the requirements of 46 CFR 197.550(b) and 197.555(c) or of 29 CFR 1910.1028; and

(4) That all respirators that I will use while on the vessel have been fitted and fit tested in accordance with 46 CFR 197.550 (c) and (d) or with 29 CFR 1910.1028.

_____

(signature of worker)

_____

(printed name of worker)

_____

(date signed by worker)

APPENDIX A TO PART 197—AIR NO–DECOMPRESSION LIMITS

The following table gives the depth versus bottom time limits for single, no-decompression, air dives made within any 12-hour period. The limit is the maximum bottom time in minutes that a diver can spend at that depth without requiring decompression beyond that provided by a normal ascent rate of 60 fsw per minute. (Although bottom time is concluded when ascent begins, a slower ascent rate would increase the bottom time thereby requiring decompression.) An amount of nitrogen remains in the tissues of a diver after any air dive, regardless of whether the dive was a decompression or no-decompression dive. Whenever another dive is made within a 12-hour period, the nitrogen remaining in the blood and body tissues of the diver must be considered when calculating his decompression.

AIR NO-DECOMPRESSION LIMITS

Depth (feet):	*No-decompression limits (minutes)*
35	310
40	200
50	100
60	60
70	50
80	40
90	30
100	25
110	20
120	15
130	10

(Source: U.S. Navy Diving Manual, 1 September 1973.)

PART 198 [RESERVED]